and cast itself in a corner. For an instant they could only blink. The figure wrapped its white arms about some object.

"You can have everything but this table; you can't have—this." The words ended in a frightened sob.

"*Esther!*"

"*Oh, Joe!*" She struggled to her feet, then shrank back against the wall. "Oh, I didn't know it was you. Go 'way! go 'way!"

"Why, Esther, what do you mean?" He started towards her, but she turned on him.

"Where is she?"

"Where's who?"

She did not reply, but standing against the wall, she stared at him with a passionate scorn.

"You don't mean Sarah Norton?" asked Joe, slowly. Esther quivered. "Why, she came to tell me of the trouble her father was trying to get me into. But how did you come here, Esther? How did you know anything about it?"

She did not answer. Her head sank.

"How did you, Esther?"

"I saw—you in the lane," she faltered, then caught up her veil as though it had been a pinafore. Joe went up to her, and Jonas Ingram took hold of Harry Barker, and the two stepped outside, but not out of ear-shot; they were still curious. They could hear Esther's sobbing voice at intervals. "I tried to make 'em stop, but they wouldn't, and I slipped in past 'em and bolted the door; and when you came, I thought it was them—and, oh! ain't they our things, Joe?"

The old man thrust his head in at the door. "Yes," he roared, then withdrew.

"And won't they take the table away?"

"No," he roared again. "I'd just like to see 'em!"

Esther wept harder. "Oh, I wish they would; I ought to give 'em up. I didn't care for them after I thought—that. It was just that I had to have something I wouldn't let go, and I tried to think only of saving the table for the water-set."

"Come mighty near bein' no water-set," muttered Jonas to himself; then he turned to his companion. "Young man, I guess they don't need us no more," he said.

When he regained his sister-in-law's, he encountered that lady carrying a steaming dish. Guests stood about under the trees or sat at the long tables.

"For mercy sakes, Jonas, have you seen Esther? She made fuss enough about havin' that dove fixed up in the parlor, and she and Joe 'ain't stood under it a minit yet."

"That's a fact," chuckled the old fellow. "They 'ain't stood under no dove of peace yet; they're just about ready to now, I reckon."

And up through the lane, all oblivious, the lovers were walking slowly. Just before they reached the gap in the wall, they paused by common consent. Cherry and apple trees drooped over the wall; these had ceased blossoming, but a tangle of wild-rose bushes was all ablush. It dropped a thick harvest of petals on the ground. Joe bent his head; and Esther, resting against his shoulder, lifted her eyes to his face. All unconsciously she took the pose of the woman in the Frohman poster. They kissed, and then went on slowly.

THE CENTURY'S PROGRESS IN PHYSICS.

BY HENRY SMITH WILLIAMS, M.D.

PART II.—THE ETHER AND PONDERABLE MATTER.

I.

"WHATEVER difficulties we may have in forming a consistent idea of the constitution of the ether, there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance or body which is certainly the largest, and probably the most uniform body of which we have any knowledge."

Such was the verdict pronounced some twenty years ago by James Clerk Maxwell, one of the very greatest of nineteenth-century physicists, regarding the existence of an all-pervading plenum in the universe, in which every particle of tangible matter is immersed. And this verdict may be said to express the attitude of the entire philosophical world of our day. Without exception, the author-

itative physicists of our time accept this plenum as a verity, and reason about it with something of the same confidence they manifest in speaking of "ponderable" matter or of energy. It is true there are those among them who are disposed to deny that this all-pervading plenum merits the name of matter. But that it is a *something*, and a vastly important something at that, all are agreed. Without it, they allege, we should know nothing of light, of radiant heat, of electricity, or magnetism; without it there would probably be no such thing as gravitation; nay, they even hint that without this strange something, ether, there would be no such thing as matter in the universe. If these contentions of the modern physicist are justified, then this intangible ether is incomparably the most important as well as the "largest and most uniform substance or body" in the universe. Its discovery may well be looked upon as the most important feat of our century.

For a discovery of our century it surely is, in the sense that all the known evidences of its existence have been gathered in this epoch. True, dreamers of all ages have, for metaphysical reasons, imagined the existence of intangible fluids in space—they had, indeed, peopled space several times over with different kinds of ethers, as Maxwell remarks—but such vague dreamings no more constituted the discovery of the modern ether than the dream of some pre-Columbian visionary that land might lie beyond the unknown waters constituted the discovery of America. In justice it must be admitted that Huyghens, the seventeenth-century originator of the undulatory theory of light, caught a glimpse of the true ether; but his contemporaries and some eight generations of his successors were utterly deaf to his claims; so he bears practically the same relation to the nineteenth-century discoverers of ether that the Norseman bears to Columbus.

The true Columbus of the ether was Thomas Young. His discovery was consummated in the early days of the present century, when he brought forward the first conclusive proofs of the undulatory theory of light. To say that light consists of undulations is to postulate something which undulates; and this something could not be air, for air exists only in infinitesimal quantity, if at all, in the interstellar spaces, through which light freely penetrates. But if not air, what then? Why, clearly, something more intangible than air; something supersensible, evading all direct efforts to detect it, yet existing everywhere in seemingly vacant space, and also interpenetrating the substance of all transparent liquids and solids, if not, indeed, of all tangible substances. This intangible something Young rechristened the Luminiferous Ether.

In the early days of his discovery Young thought of the undulations which produce light and radiant heat as being longitudinal—a forward and backward pulsation, corresponding to the pulsations of sound—and as such pulsations can be transmitted by a fluid medium with the properties of ordinary fluids, he was justified in thinking of the ether as being like a fluid in its properties, except for its extreme intangibility. But about 1818 the experiments of Fresnel and Arago with polarization of light made it seem very doubtful whether the theory of longitudinal vibrations is sufficient, and it was suggested by Young, and independently conceived and demonstrated by Fresnel, that the luminiferous undulations are not longitudinal, but transverse; and all the more recent experiments have tended to confirm this view. But it happens that ordinary fluids—gases and liquids—cannot transmit lateral vibrations; only rigid bodies are capable of such a vibration. So it became necessary to assume that the luminiferous ether is a body possessing elastic rigidity—a familiar property of tangible solids, but one quite unknown among fluids.

The idea of transverse vibrations carried with it another puzzle. Why does not the ether, when set aquiver with the vibration which gives us the sensation we call light, have produced in its substance subordinate quivers, setting out at right angles from the path of the original quiver? Such perpendicular vibrations seem not to exist, else we might see around a corner; how explain their absence? The physicists could think of but one way: they must assume that the ether is incompressible. It must fill all space—at any rate, all space with which human knowledge deals—perfectly full.

These properties of the ether, incompressibility and elastic rigidity, are quite conceivable by themselves; but difficulties

of thought appear when we reflect upon another quality which the ether clearly must possess — namely, frictionlessness. Per hypothesis this rigid, incompressible body pervades all space, imbedding every particle of tangible matter; yet it seems not to retard the movements of this matter in the slightest degree. This is undoubtedly the most difficult to comprehend of the alleged properties of the ether. The physicist explains it as due to the perfect elasticity of the ether, in virtue of which it closes in behind a moving particle with a push exactly counterbalancing the stress required to penetrate it in front.

To a person unaccustomed to think of seemingly solid matter as really composed of particles relatively wide apart, it is hard to understand the claim that ether penetrates the substance of solids—of glass, for example—and, to use Young's expression, which we have previously quoted, moves among them as freely as the wind moves through a grove of trees. This thought, however, presents few difficulties to the mind accustomed to philosophical speculation. But the question early arose in the mind of Fresnel whether the ether is not considerably affected by contact with the particles of solids. Some of his experiments led him to believe that a portion of the ether which penetrates among the molecules of tangible matter is held captive, so to speak, and made to move along with these particles. He spoke of such portions of the ether as "bound" ether, in contradistinction to the great mass of "free" ether. Half a century after Fresnel's death, when the ether hypothesis had become an accepted tenet of science, experiments were undertaken by Fizeau in France, and by Maxwell in England, to ascertain whether any portion of ether is really thus bound to particles of matter; but the results of the experiments were negative, and the question is still undetermined.

While the undulatory theory of light was still fighting its way, another kind of evidence favoring the existence of an ether was put forward by Michael Faraday, who, in the course of his experiments in electrical and magnetic induction, was led more and more to perceive definite lines or channels of force in the medium subject to electro-magnetic influence. Faraday's mind, like that of Newton and many other philosophers, rejected the idea of action at a distance, and he felt convinced that the phenomena of magnetism and of electric induction told strongly for the existence of an invisible plenum everywhere in space, which might very probably be the same plenum that carried the undulations of light and radiant heat.

Then about the middle of the century came that final revolution of thought regarding the nature of energy, which we have already outlined in the preceding paper, and with that the case for ether was considered to be fully established. The idea that energy is merely a "mode of motion" (to adopt Tyndall's familiar phrase), combined with the universal rejection of the notion of action at a distance, made the acceptance of a plenum throughout space a necessity of thought—so, at any rate, it has seemed to most physicists of recent decades. The proof that all known forms of radiant energy move through space at the same rate of speed is regarded as practically a demonstration that but one plenum—one ether—is concerned in their transmission. It has, indeed, been tentatively suggested, by Professor J. Oliver Lodge, that there may be two ethers, representing the two opposite kinds of electricity, but even the author of this hypothesis would hardly claim for it a high degree of probability.

The most recent speculations regarding the properties of the ether have departed but little from the early ideas of Young and Fresnel. It is assumed on all sides that the ether is a continuous, incompressible body, possessing rigidity and elasticity. Lord Kelvin has even calculated the probable density of this ether, and its coefficient of rigidity. As might be supposed, it is all but infinitely tenuous as compared with any tangible solid, and its rigidity is but infinitesimal as compared with that of steel. In a word, it combines properties of tangible matter in a way not known in any tangible substance. Therefore we cannot possibly conceive its true condition correctly. The nearest approximation, according to Lord Kelvin, is furnished by a mould of transparent jelly. It is a crude, inaccurate analogy, of course, the density and resistance of jelly in particular being utterly different from those of the ether; but the quivers that run through the jelly when it is shaken, and the elastic tension under which it is placed when its mass is twist-

ed about, furnish some analogy to the quivers and strains in the ether, which are held to constitute radiant energy, magnetism, and electricity.

The great physicists of the day being at one regarding the existence of this all-pervading ether, it would be a manifest presumption for any one standing without the pale to challenge so firmly rooted a belief. And, indeed, in any event, there seems little ground on which to base such a challenge. Yet it may not be altogether amiss to reflect that the physicist of to-day is no more certain of his ether than was his predecessor of the eighteenth century of the existence of certain alleged substances which he called phlogiston, caloric, corpuscles of light, and magnetic and electric fluids. It would be but the repetition of history should it chance that before the close of another century the ether should have taken its place along with these discarded creations of the scientific imagination of earlier generations. The philosopher of to-day feels very sure that an ether exists; but when he says there is "no doubt" of its existence he speaks incautiously, and steps beyond the bounds of demonstration. He does not *know* that action cannot take place at a distance; he does not *know* that empty space itself may not perform the functions which he ascribes to his space-filling ether.

II.

Meantime, however, the ether, be it substance or be it only dream-stuff, is serving an admirable purpose in furnishing a fulcrum for modern physics. Not alone to the student of energy has it proved invaluable, but to the student of matter itself as well. Out of its hypothetical mistiness has been reared the most tenable theory of the constitution of ponderable matter which has yet been suggested—or, at any rate, the one that will stand as the definitive nineteenth-century guess at this "riddle of the ages." I mean, of course, the vortex theory of atoms — that profound and fascinating doctrine which suggests that matter, in all its multiform phases, is nothing more or less than ether in motion.

The author of this wonderful conception is Lord Kelvin. The idea was born in his mind of a happy union of mathematical calculations with concrete experiments. The mathematical calculations were largely the work of Hermann von Helmholtz, who, about the year 1858, had undertaken to solve some unique problems in vortex motions. Helmholtz found that a vortex whirl, once established in a frictionless medium, must go on, theoretically, unchanged forever. In a limited medium such a whirl may be V-shaped, with its ends at the surface of the medium. We may imitate such a vortex by drawing the bowl of a spoon quickly through a cup of water. But in a limitless medium the vortex whirl must always be a closed ring, which may take the simple form of a hoop or circle, or which may be indefinitely contorted, looped, or, so to speak, knotted. Whether simple or contorted, this endless chain of whirling matter (the particles revolving about the axis of the loop as the particles of a string revolve when the string is rolled between the fingers) must, in a frictionless medium, retain its form, and whirl on with undiminished speed forever.

While these theoretical calculations of Helmholtz were fresh in his mind, Lord Kelvin (then Sir William Thomson) was shown by Professor E. B. Tait, of Edinburgh, an apparatus constructed for the purpose of creating vortex rings in air. The apparatus, which any one may duplicate, consisted simply of a box with a hole bored in one side, and a piece of canvas stretched across the opposite side in lieu of boards. Fumes of chloride of ammonia are generated within the box, merely to render the air visible. By tapping with the hand on the canvas side of the box, vortex rings of the clouded air are driven out, precisely similar in appearance to those smoke rings which some expert tobacco-smokers can produce by tapping on their cheeks, or to those larger ones which we sometimes see blown out from the funnel of a locomotive.

The advantage of Professor Tait's apparatus is its manageableness, and the certainty with which the desired result can be produced. Before Lord Kelvin's interested observation it threw out rings of various sizes, which moved straight across the room at varying rates of speed, according to the initial impulse, and which behaved very strangely when coming in contact with one another. If, for example, a rapidly moving ring overtook another moving in the same path, the one in advance seemed to pause, and to spread

out its periphery like an elastic band, while the pursuer seemed to contract, till it actually slid through the orifice of the other, after which each ring resumed its original size, and continued its course as if nothing had happened. When, on the other hand, two rings moving in slightly different directions came near each other, they seemed to have an attraction for each other; yet if they impinged, they bounded away, quivering like elastic solids. If an effort were made to grasp or to cut one of these rings, the subtle thing shrunk from the contact, and slipped away as if it were alive.

And all the while the body which thus conducted itself consisted simply of a whirl in the air, made visible, but not otherwise influenced, by smoky fumes. Presently the friction of the surrounding air wore the ring away, and it faded into the general atmosphere—often, however, not until it had persisted for many seconds, and passed clear across a large room. Clearly, if there were no friction, the ring's inertia must make it a permanent structure. Only the frictionless medium was lacking to fulfil all the conditions of Helmholtz's indestructible vortices. And at once Lord Kelvin bethought him of the frictionless medium which physicists had now begun to accept—the all-pervading ether. What if vortex rings were started in this ether, must they not have the properties which the vortex rings in air had exhibited—inertia, attraction, elasticity? And are not these the properties of ordinary tangible matter? Is it not probable, then, that what we call matter consists merely of aggregations of infinitesimal vortex rings in the ether?

Thus the vortex theory of atoms took form in Lord Kelvin's mind, and its expression gave the world what most philosophers of our time regard as the most plausible conception of the constitution of matter hitherto formulated. It is only a theory, to be sure; its author would be the last person to claim finality for it. But it has a basis in mathematical calculation and in analogical experiment such as no other theory of matter can lay claim to, and it has a unifying or monistic tendency that makes it, for the philosophical mind, little less than fascinating. True or false, it is the definitive theory of matter of the nineteenth century.

III.

Quite aside from the question of the exact constitution of the ultimate particles of matter, questions as to the distribution of such particles, their mutual relations, properties, and actions, have come in for a full share of attention during our century, though the foundations for the modern speculations were furnished in a previous epoch. The most popular eighteenth-century speculation as to the ultimate constitution of matter was that of the learned Italian priest, Roger Joseph Boscovich, published in 1758, in his *Theoria Philosophiæ Naturalis.* "In this theory," according to an early commentator, "the whole mass of which the bodies of the universe are composed is supposed to consist of an exceedingly great yet finite number of simple, indivisible, inextended atoms. These atoms are endued by the Creator with *repulsive* and *attractive* forces, which vary according to the distance. At very small distances the particles of matter repel each other; and this repulsive force increases beyond all limits as the distances are diminished, and will consequently forever prevent actual contact. When the particles of matter are removed to sensible distances, the repulsive is exchanged for an attractive force, which decreases in inverse ratio with the squares of the distances, and extends beyond the spheres of the most remote comets."

This conception of the atom as a mere centre of force was hardly such as could satisfy any mind other than the metaphysical. No one made a conspicuous attempt to improve upon the idea, however, till just at the close of the century, when Humphry Davy was led, in the course of his studies of heat, to speculate as to the changes that occur in the intimate substance of matter under altered conditions of temperature. Davy, as we have seen, regarded heat as a manifestation of motion among the particles of matter. As all bodies with which we come in contact have some temperature, Davy inferred that the intimate particles of every substance must be perpetually in a state of vibration. Such vibrations, he believed, produced the "repulsive force" which (in common with Boscovich) he admitted as holding the particles of matter at a distance from one another. To heat a substance means merely to increase the rate of vibration

of its particles; thus also, plainly, increasing the repulsive forces, and expanding the bulk of the mass as a whole. If the degree of heat applied be sufficient, the repulsive force may become strong enough quite to overcome the attractive force, and the particles will separate and tend to fly away from one another, the solid then becoming a gas.

Not much attention was paid to these very suggestive ideas of Davy, because they were founded on the idea that heat is merely a motion, which the scientific world then repudiated; but half a century later, when the new theories of energy had made their way, there came a revival of practically the same ideas of the particles of matter (molecules they were now called) which Davy had advocated. Then it was that Clausius in Germany and Clerk Maxwell in England took up the investigation of what came to be known as the kinetic theory of gases—the now familiar conception that all the phenomena of gases are due to the helter-skelter flight of the showers of widely separated molecules of which they are composed. The specific idea that the pressure or "spring" of gases is due to such molecular impacts was due to Daniel Bournelli, who advanced it early in the eighteenth century. The idea, then little noticed, had been revived about a century later by William Herapath, and again with some success by J. J. Waterston, of Bombay, about 1846; but it gained no distinct footing until taken in hand by Clausius in 1857 and by Maxwell in 1859.

The investigations of these great physicists not only served fully to substantiate the doctrine, but threw a flood of light upon the entire subject of molecular dynamics. Soon the physicists came to feel as certain of the existence of these showers of flying molecules making up a gas as if they could actually see and watch their individual actions. Through study of the viscosity of gases—that is to say, of the degree of frictional opposition they show to an object moving through them, or to another current of gas—an idea was gained, with the aid of mathematics, of the rate of speed at which the particles of the gas are moving, and the number of collisions which each particle must experience in a given time, and of the length of the average free path traversed by the molecule between collisions. These measurements were confirmed by study of the rate of diffusion at which different gases mix together, and also by the rate of diffusion of heat through a gas, both these phenomena being chiefly due to the helter-skelter flight of the molecules.

It is sufficiently astonishing to be told that such measurements as these have been made at all, but the astonishment grows when one hears the results. It appears from Maxwell's calculations that the mean free path, or distance traversed by the molecules between collisions in ordinary air, is about one half-millionth of an inch; while the speed of the molecules is such that each one experiences about eight billions of collisions per second! It would be hard, perhaps, to cite an illustration showing the refinements of modern physics better than this; unless, indeed, one other result that followed directly from these calculations be considered such — the feat, namely, of measuring the size of the molecules themselves. Clausius was the first to point out how this might be done from a knowledge of the length of free path; and the calculations were made by Loschmidt in Germany, and by Lord Kelvin in England, independently.

The work is purely mathematical, of course, but the results are regarded as unassailable; indeed, Lord Kelvin speaks of them as being absolutely demonstrative, within certain limits of accuracy. This does not mean, however, that they show the exact dimensions of the molecule; it means an estimate of the limits of size within which the actual size of the molecule may lie. These limits, Lord Kelvin estimates, are about the one ten-millionth of a centimetre for the maximum, and the one one-hundred-millionth of a centimetre for the minimum. Such figures convey no particular meaning to our blunt senses, but Lord Kelvin has given a tangible illustration that aids the imagination to at least a vague comprehension of the unthinkable smallness of the molecule. He estimates that if a ball, say of water or glass, about "as large as a football, were to be magnified up to the size of the earth, each constituent molecule being magnified in the same proportion, the magnified structure would be more coarse-grained than a heap of shot, but probably less coarse-grained than a heap of footballs."

Several other methods have been em-

ployed to estimate the size of molecules. One of these is based upon the phenomena of contact electricity; another upon the wave theory of light; and another upon capillary attraction, as shown in the tense film of a soap-bubble! No one of these methods gives results more definite than that due to the kinetic theory of gases, just outlined; but the important thing is that the results obtained by these different methods (all of them due to Lord Kelvin) agree with one another in fixing the dimensions of the molecule at somewhere about the limits already mentioned. We may feel very sure indeed, therefore, that the ultimate particles of matter are not the unextended, formless points which Boscovich and his followers of the last century thought them.

IV.

Whatever the exact form of the molecule, its outline is subject to incessant variation; for nothing in molecular science is regarded as more firmly established than that the molecule, under all ordinary circumstances, is in a state of intense but variable vibration. The entire energy of a molecule of gas, for example, is not measured by its momentum, but by this plus its energy of vibration and rotation, due to the collisions already referred to. Clausius has even estimated the relative importance of these two quantities, showing that the translational motion of a molecule of gas accounts for only three-fifths of its kinetic energy. The total energy of the molecule (which we call "heat") includes also another factor, namely, potential energy, or energy of position, due to the work that has been done on expanding, in overcoming external pressure, and internal attraction between the molecules themselves. This potential energy (which will be recovered when the gas contracts) is the "latent heat" of Black, which so long puzzled the philosophers. It is latent in the same sense that the energy of a ball thrown into the air is latent at the moment when the ball poises at its greatest height before beginning to fall.

It thus appears that a variety of motions, real and potential, enter into the production of the condition we term heat. It is, however, chiefly the translational motion which is measurable as temperature; and this, too, which most obviously determines the physical state of the substance that the molecules collectively compose —whether, that is to say, it shall appear to our blunt perceptions as a gas, a liquid, or a solid. In the gaseous state, as we have seen, the translational motion of the molecules is relatively enormous, the molecules being widely separated. It does not follow, as was formerly supposed, that this is evidence of a repulsive power acting between the molecules. The physicists of to-day, headed by Lord Kelvin, decline to recognize any such power. They hold that the molecules of a gas fly in straight lines in virtue of their inertia, quite independently of one another, except at times of collision, from which they rebound in virtue of their elasticity; or an approach to collision, in which latter case, coming within the range of mutual attraction, two molecules may circle about one another, as a comet circles about the sun, then rush apart again, as the comet rushes from the sun.

It is obvious that the length of the mean free path of the molecules of a gas may be increased indefinitely by decreasing the number of the molecules themselves in a circumscribed space. It has been shown by Professors Tait and Dewar that a vacuum may be produced artificially of such a degree of rarefaction that the mean free path of the remaining molecules is measurable in inches. The calculation is based on experiments made with the radiometer of Professor Crookes, an instrument which in itself is held to demonstrate the truth of the kinetic theory of gases. Such an attenuated gas as this is considered by Professor Crookes as constituting a fourth state of matter, which he terms ultra-gaseous.

If, on the other hand, a gas is subjected to pressure, its molecules are crowded closer together, and the length of their mean free path is thus lessened. Ultimately, the pressure being sufficient, the molecules are practically in continuous contact. Meantime the enormously increased number of collisions has set the molecules more and more actively vibrating, and the temperature of the gas has increased, as, indeed, necessarily results in accordance with the law of the conservation of energy. No amount of pressure, therefore, can suffice by itself to reduce the gas to a liquid state. It is believed that even at the centre of the sun, where the pressure is almost inconceivably great, all matter is to be regarded as really gaseous, though the

molecules must be so packed together that the consistency is probably more like that of a solid.

If, however, coincidently with the application of pressure, opportunity be given for the excess of heat to be dissipated to a colder surrounding medium, the molecules, giving off their excess of energy, become relatively quiescent, and at a certain stage the gas becomes a liquid. The exact point at which this transformation occurs, however, differs enormously for different substances. In the case of water, for example, it is a temperature more than four hundred degrees above zero, Centigrade; while for atmospheric air it is 194° Centigrade below zero, or more than a hundred and fifty degrees below the point at which mercury freezes.

Be it high or low, the temperature above which any substance is always a gas, regardless of pressure, is called the critical temperature, or absolute boiling-point, of that substance. It does not follow, however, that below this point the substance is necessarily a liquid. This is a matter that will be determined by external conditions of pressure. Even far below the critical temperature the molecules have an enormous degree of activity, and tend to fly asunder, maintaining what appears to be a gaseous, but what technically is called a vaporous, condition—the distinction being that pressure alone suffices to reduce the vapor to the liquid state. Thus water may change from the gaseous to the liquid state at 400° above zero, but under conditions of ordinary atmospheric pressure it does not do so until the temperature is lowered three hundred degrees further. Below 400°, however, it is technically a vapor, not a gas; but the sole difference, it will be understood, is in the degree of molecular activity.

It thus appears that the prevalence of water in a vaporous and liquid rather than in a "permanently" gaseous condition here on the globe is a mere incident of telluric evolution. Equally incidental is the fact that the air we breathe is "permanently" gaseous and not liquid or solid, as it might be were the earth's surface temperature to be lowered to a degree which, in the larger view, may be regarded as trifling. Between the atmospheric temperature in tropical and in arctic regions there is often a variation of more than one hundred degrees; were the temperature reduced another hundred, the point would be reached at which oxygen gas becomes a vapor, and under increased pressure would be a liquid. Thirty-seven degrees more would bring us to the critical temperature of nitrogen.

Nor is this a mere theoretical assumption; it is a determination of experimental science, quite independent of theory. The physicist in the laboratory has produced artificial conditions of temperature enabling him to change the state of the most persistent gases. Some fifty years since, when the kinetic theory was in its infancy, Faraday liquefied carbonic acid gas, among others, and the experiments thus inaugurated have been extended by numerous more recent investigators, notably by Cailletet in Switzerland, by Pictet in France, and by Dr. Thomas Andrews and Professor James Dewar in England. In the course of these experiments not only has air been liquefied, but hydrogen also, the most subtle of gases; and it has been made more and more apparent that gas and liquid are, as Andrews long ago asserted, "only distant stages of a long series of continuous physical changes." Of course if the temperature be lowered still further, the liquid becomes a solid; and this change also has been effected in the case of some of the most "permanent" gases, including air.

The degree of cold—that is, of absence of heat—thus produced is enormous, relatively to anything of which we have experience in nature here at the earth now, yet the molecules of solidified air, for example, are not absolutely quiescent. In other words, they still have a temperature, though so very low. But it is clearly conceivable that a stage might be reached at which the molecules became absolutely quiescent, as regards either translational or vibratory motion. Such a heatless condition has been approached, but as yet not quite attained, in laboratory experiments. It is called the absolute zero of temperature, and is estimated to be equivalent to 273° Centigrade below the freezing-point of water, or ordinary zero.

A temperature (or absence of temperature) closely approximating this is believed to obtain in the ethereal ocean of interplanetary and interstellar space, which transmits, but is thought not to absorb, radiant energy. We here on the earth's surface are protected from exposure to this cold, which would deprive

every organic thing of life almost instantaneously, solely by the thin blanket of atmosphere with which the globe is coated. It would seem as if this atmosphere, exposed to such a temperature at its surface, must there be incessantly liquefied, and thus fall back like rain to be dissolved into gas again while it still is many miles above the earth's surface. This may be the reason why its scurrying molecules have not long ago wandered off into space, and left the world without protection.

But whether or not such liquefaction of the air now occurs in our outer atmosphere, there can be no question as to what must occur in its entire depth were we permanently shut off from the heating influence of the sun, as the astronomers threaten that we may be in a future age. Each molecule, not alone of the atmosphere, but of the entire earth's substance, is kept aquiver by the energy which it receives, or has received, directly or indirectly, from the sun. Left to itself, each molecule would wear out its energy and fritter it off into the space about it, ultimately running completely down, as surely as any human-made machine whose power is not from time to time restored. If then it shall come to pass in some future age that the sun's rays fail us, the temperature of the globe must gradually sink toward the absolute zero. That is to say, the molecules of gas which now fly about at such inconceivable speed must drop helpless to the earth; liquids must in turn become solids; and solids themselves, their molecular quivers utterly stilled, may perhaps take on properties the nature of which we cannot surmise.

Yet even then, according to the current hypothesis, the heatless molecule will still be a thing instinct with life. Its vortex whirl will still go on, uninfluenced by the dying out of those subordinate quivers that produced the transitory effect which we call temperature. For those transitory thrills, though determining the physical state of matter as measured by our crude organs of sense, were no more than non-essential incidents; but the vortex whirl is the essence of matter itself.

SHARON'S CHOICE.

BY OWEN WISTER.

UNDER Providence, a man may achieve the making of many things—ships, books, fortunes, himself even, quite often enough to encourage others; but let him beware of creating a town. Towns mostly happen. No real-estate operator decided that Rome should be. Sharon was an intended town; a one man's piece of deliberate manufacture; his whim, his pet, his device for immortally continuing above ground. He planned its avenues, gave it his middle name, fed it with his railroad. But he had reckoned without the inhabitants (to say nothing of nature), and one day they displeased him. Whenever you wish you can see Sharon and what it has come to, as I saw it when, as a visitor without local prejudices, they asked me to serve with the telegraph-operator and the ticket-agent and the hotel-manager on the literary committee of judges at the school festival. There would be a stage, and flags, and elocution, and parents assembled, and afterwards ice-cream with strawberries from El Paso.

"Have you ever awarded prizes for school speaking?" inquired the telegraph-operator, Stuart.

"Yes," I told him. "At Concord in New Hampshire."

"Ever have a chat afterwards with a mother whose girl did not get the prize?"

"It was boys," I replied. "And parents had no say in it."

"It's boys and girls in Sharon," said he. "Parents have no say in it here, either. But that don't seem to occur to them at the moment. We'll all stick together, of course."

"I think I had best resign," said I. "You would find me no hand at pacifying a mother."

"There are fathers also," said Stuart. "But individual parents are small trouble compared with a big split in public opinion. We've missed that so far, though."

"Then why have judges? Why not a popular vote?" I inquired.

"Don't go back on us," said Stuart. "We are so few here. And you know education can't be democratic, or where will good taste find itself? Eastman knows that much, at least." And Stuart explained that Eastman was the head of the school and chairman of our committee. "He is from Massachusetts, and his